CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-203
INDEPENDENCE FAULT ZONE AND RELATED FAULTS
WESTERN INYO COUNTY, CALIFORNIA

by

William A. Bryant
Associate Geologist
March 1, 1989

INTRODUCTION

The Independence fault zone and associated faults in western Inyo County are evaluated in this Fault Evaluation Report (FER) (Figure 1). The western Owens Valley study area is located in parts of the Lone Pine, Mt. Langley, Manzanar, Mt. Williamson, Kearsarge Peak, and Aberdeen 7.5-minute quadrangles (Figure 1). Traces of the Independence fault zone in the western Owens Valley study area are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act of 1972 (Hart, 1985).

SUMMARY OF AVAILABLE DATA

The western Owens Valley study area is located in a major, north-trending fault-bounded depression situated between the Sierra Nevada to the west and the White-Inyo Mountains to the east (Figure 1). The study area is located in the western part of the Basin and Range geomorphic province and is characterized by oblique Basin and Range extensional tectonics which results in both normal and right-lateral displacement along north to northwest-trending faults.

Topography in the study area ranges from gently eastward-sloping bajadas to the extremely rugged eastern escarpment of the Sierra Nevada. Elevations in the study area range from 1100 meters to 3900 meters above sea level. Development in the study area is low and most of the area is used for agricultural and recreational purposes. The towns of Lone Pine and Independence are located 10 km and 7 km east of the Independence fault zone, respectively.

Rock types in the study area include Mesozoic plutonic rocks (mainly granitic), minor Tertiary and Quaternary volcanic rocks, and Quaternary glacial and alluvial deposits (Moore, 1963, 1981; Gillespie, 1982; Matthews and Burnett, 1965). Significant late Quaternary glacial deposits include tills from the Tahoe (60 to 120ka), Tenaya (~50 ka), and Tioga (13 to 20 ka) glacial stages.

Independence Fault Zone

The Independence fault zone is a major, north northwest-trending range-front fault that borders the east side of the Sierra Nevada for approximately 40 km (Figures 1, 2a-2c). The Independence fault zone, which is a part of the Sierra Nevada fault zone, is characterized by approximately 1800 meters of down-to-the-east vertical displacement (Gillespie, 1982). Approximately half the subsidence of Owens Valley may have occurred along this fault zone. Strike-slip displacement has not been reported for the Independence fault zone.

Mapping of the Independence fault zone that will be evaluated in this FER includes Slemmons and students (1970), Moore (1963, 1981), and Gillespie (1982). Knopf (1918) mapped two traces of the Independence fault zone in the study area, one south of Shepard Creek and one just north of George Creek. However, Knopf will not be evaluated in this FER because of the small scale of mapping (1:125,000). The Independence fault zone will be evaluated from south to north.

Slemmons and students (1970) mapped most of the Independence fault zone and additional lineaments east of the Independence fault at a scale of 1:62,500, based on interpretation of low-sun-angle aerial photographs and limited field mapping (shown in pink on Figures 2a-2c). Maps by Slemmons and students are not annotated and lack an explanation, the orientation of fault scarps is not indicated, and the quality of the base maps is poor. These maps, significant parts of which were mapped by University of Nevada, Reno graduate students, probably should be considered to be lineament maps rather than fault maps.

Mapping by Slemmons and students is the only relatively large-scale mapping available for the Independence fault zone in the Lone Pine, Mt. Langley, and Manzanar 7.5-minute quadrangles (Figures 2a and 2b). The Independence fault zone mapped by Slemmons and students is a complex, northwest-trending zone of discontinuous lineaments in late

Quaternary alluvium and Mesozoic bedrock along the east side of the Sierra Nevada. It is difficult to evaluate lineaments mapped by Slemmons and students because there is no indication of deposits offset and there are no annotations of geomorphic features indicative of fault recency.

Moore (1981) mapped traces of the Independence fault zone in the Mt. Williamson 7.5-minute quadrangle (NE 1/4 of the Mt. Whitney 15-minute quadrangle) (shown in blue-green on Figure 2b). Moore (1981) did not differentiate the ages of Quaternary alluvial deposits. However, it is assumed in this FER that Moore's Qal unit is latest Pleistocene to Holocene in age. Moore (1981) mapped two strands of the Independence fault zone in the study area. The eastern branch offsets his Qal alluvial unit and is delineated by an east-facing scarp (locality 1, Figure 2b). Moore's western branch fault is located mostly in granitic bedrock, but the northern extent of this fault offsets Qal alluvium (Figure 2b).

Moore (1963) mapped traces of the Independence fault zone in the Kearsarge Peak and Aberdeen 7.5-minute quadrangles (NE and SE 1/4's of the Mt. Pinchot 15-minute quadrangle) (shown in brown on Figure 2c). Moore (1963) reported that displacement along the Independence fault zone, which dips 45° to 50° to the east, is normal dip-slip; evidence of a significant component of strike-slip displacement was not observed.

Traces of the Independence fault zone mapped by Moore (1963) form a zone of complex, discontinuous, generally down to the east normal faults. Faults mapped by Moore (1963) do not correspond with traces mapped by Slemmons and students (1970) (Figure 2c). Holocene deposits (designated as Recent by Moore) are offset in Independence Creek (locality 2), just north of Independence Creek (locality 3), in Thibaut Creek (locality 4), and in the North Fork of Oat Creek (locality 5) (Figure 2c). Bedrock is juxtaposed against Holocene alluvium just north of the South Fork of Oak Creek (Figure 2c). A short, northeast-trending fault mapped by Moore offsets Holocene alluvium just north of Goodale Creek near the northern end of the Aberdeen quadrangle (localities 6 and 7, Figure 2c).

Gillespie (1982) mapped traces of the Independence fault zone at a scale of 1:62,500 in the Kearsarge Peak and Aberdeen 7.5-minute quadrangles (NE and SE 1/4's of the Mt. Pinchot 15-minute quadrangle) (shown in orange on Figure 2c). Gillespie reported that faulting has extended into the Holocene at Independence Creek (locality 8, Figure 2c).

Here, a late Tioga terrace is vertically offset about 1.4 meters (Photo 2). Just north of Independence Creek a Holocene landslide [rock avalanche] is vertically offset about 2 meters (Gillespie, 1982, p. 483) (locality 3, Figure 2c). Additional areas where Gillespie reported evidence of Holocene displacement include the areas south of Sawmill Creek and near Shingle Mill Bench (localities 9 and 10, Figure 2c). From Sardine Canyon north to Thibaut Creek, and from Sawmill Creek north to Taboose Creek, even early Wisconsin moraines are apparently unfaulted (Figure 2c).

Traces of the Independence fault zone mapped by Gillespie generally correspond with traces mapped by Moore (1963), although differences in detail exist (Figure 2c). Lineaments mapped by Slemmons and students (1970) only locally correspond with traces of the Independence fault zone mapped by Gillespie (1982) and Moore (1963) (Figure 2c).

Discontinuous traces of the Independence fault continue north of the study area, but will not be evaluated in this FER because of time constraints and a lack of air photo coverage.

Late Quaternary slip-rates vary along different segments of the Independence fault zone, according to Gillespie (1982). Gillespie concluded that the average slip-rate is probably 0.35 mm/yr. However, at Independence Creek Gillespie reported that the slip-rate is probably 0.12 mm/yr. Pleistocene intracanyon lava flows that are inferred by Gillespie to be offset at Sawmill Creek suggest an average late Pleistocene slip-rate of 0.5 mm/yr, which is considerably higher than estimates for other strands of the Independence fault zone.

Lineaments North of Alabama Hills

Slemmons and students (1970) mapped a broad, northwest-trending zone of tonal lineaments north of the Alabama Hills and west of Highway 395 (Figure 2b). The western part of this zone, which is up to 2 km wide, very loosely corresponds with a zone of right-stepping faults mapped by Matthews and Burnett (1965) (Figures 1 and 2b).

Many additional lineaments were mapped by Slemmons and students between the Independence fault zone and the Owens Valley fault zone to the east (Figure 1). Some of these lineaments are plotted in this FER, but most are not. A very brief reconnaissance air photo interpretation of these un-plotted lineaments was made; these lineaments were not verified by this writer as recently active faults. Some of these lineaments are vague tonal lineaments or vegetation contrasts that may be non-fault related ground failures associated with the 1872 Owens Valley earthquake.

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD OBSERVATIONS

Aerial photographic interpretation by this writer of faults in the western Owens Valley study area was accomplished using U.S. Bureau of Land Management (1977, CA01-77, approximate scale 1:24,000), University of Nevada, Reno (1968, OV-9-11, approximate scale 1:12,000), and U.S. Geological Survey (1955, GS-VJZ, approximate scale 1:54,000) aerial photographs. Air photo coverage available for this evaluation of the Independence fault zone is not complete; significant areas that lack stereo coverage include the Independence Creek area where Gillespie (1982) reported evidence of Holocene displacement, and most of the Independence fault zone mapped by Gillespie and Moore (1963) west of the range front in the Kearsage Peak and Aberdeen 7.5-minute quadrangles (Figure 2c).

Approximately 2 1/2 days were spent in the field in August 1988 by this writer. Selected fault traces were verified and subtle features not observable on the aerial photographs were mapped in the field. Results of aerial photographic interpretation and field observations by this writer are summarized on Figures 2c, 3a, and 3b.

Fault scarp heights and scarp-slope angles were measured in order to estimate recency of faulting, based on the work of Wallace (1977). A direct correlation between the ages indicated by fault scarp profiles measured by Wallace (1977) in Nevada and scarp profiles measured during investigations for this FER cannot be made due to different lithology, climate, and style of faulting (Mayer, 1982). However, the data presented by Wallace (1977, 1978) can be used as a guide (or additional factor) when evaluating the geomorphic features and age of offset deposits (when known) for recency of faulting. Some very general guidelines for estimating scarp ages are summarized as follows. Fault scarp angles for faults in unconsolidated alluvium and colluvium no older than 10,000 to 12,000 yrs BP can range from 10° to 35° (Wallace, 1977). The average scarp angle is about 22°, based on Figure 8 of Wallace (1977), although Figure 12 of Wallace (1977) indicates that scarp angles of about 19° represent minimum Holocene age. The scarp crest width for scarps no older than about 10,000 yrs BP ranges from 1 to about 6 meters (Wallace, 1977, Figure 11). Wide variations occur, but these figures probably represent minimum criteria suggesting Holocene displacement.

Independence Fault Zone

Traces of the Independence fault zone in the western Owens valley study area are moderately to moderately well-defined in the Lone Pine, Mt. Langley, Manzanar, and Mt. Williamson 7.5-minute quadrangles (Figures 3a and 3b). North of the Mt. Williamson quadrangle the fault zone is generally less well-defined, although air photo coverage is not complete in this area (Figure 2c).

The Independence fault zone in the Lone Pine and Mt. Langley quadrangles is moderately well-defined and is delineated by geomorphic evidence of latest Pleistocene and Holocene normal displacement, such as scarps in latest Pleistocene and Holocene alluvium, talus, and colluvium, vertically offset drainages, and tonal lineaments in Holocene alluvium (e.g. localities 11 to 16, Figure 3a). Fault scarp profiles at localities 12 and 15 (Figure 3a), with scarp slope angles of around 25°, further suggest Holocene displacement along this part of the Independence fault zone (Figure 3a).

Lineaments mapped by Slemmons and students (1970) in the Lone Pine and Mt. Langley quadrangles generally were not verified as recently active faults by this writer, based on air photo interpretation and limited field checking (Figures 2a, 3a). Those traces that were verified were often mis-located as much as 180 meters.

Traces of the Independence fault zone in the Manzanar and Mt. Williamson quadrangles are generally well-defined and are characterized by geomorphic evidence of latest Pleistocene and Holocene normal faulting, such as scarps in latest Pleistocene to Holocene alluvial fans and terraces, vertically offset drainages, and tonal lineaments in Holocene alluvium (e.g. localities 17 to 23, Figure 3b).

The eastern branch of the Independence fault zone mapped by Moore (1981) was verified by this writer, although differences in detail exist (Figures 2b and 3b). The western branch is poorly defined and was not verified as a recently active fault (Figure 2b).

Lineaments mapped by Slemmons and students (1970) in the Manazanar quadrangle were not verified as recently active faults by this writer, based on air photo interpretation (Figure 2b). Slemmons and students did not map lineaments in the Mt. Williason quadrangle.

The fault mapped by Gillespie in Independence Creek was verified by this writer, based on field observations in August 1988 (locality 8, Figure 2c). The fault is well-defined and offsets glacial outwash deposits Gillespie has identified as late Tioga (~13,000 ybp; 1.4 meter scarp in outwash deposits reported by Gillespie, 1982, p.483; Photo 2). A Holocene landslide that Gillespie mapped as offset by this branch of the Independence fault zone was verified by this writer and is probably best described as a rock avalanche (locality 3, Figure 2c). This area is not covered by stereo airphotos, but single frame coverage shows a lineament crossing the rock avalanche that is continuous with this branch of the Independence fault zone. The tonal lineament is consistent with the interpretation of a 2 meter-high scarp.

The Independence fault zone 2 - 3 km south of Sawmill Creek is delineated by a short, moderately defined east-facing scarp in late Pleistocene to Holocene alluvium (locality 9, Figure 2c). Faults mapped by Gillespie near this location were partly verified by this writer, although differences in location exist. The Shingle Mill Bench area is not covered by air photos, is mostly inaccessible, and therefore was not evaluated (locality 10, Figure 2c).

Alluvial fans that flank the eastern Sierra Nevada in the FER study area are almost always entrenched at the fan head and for a considerable distance to the east. Savage and others (1975) reported that eastward tilting of the Sierra Nevada (or relative subsidence of Owens Valley) is occurring at a rate of about 2.2 mm/yr. The hinge line of this eastward tilting occurs very near the Owens Valley fault zone. Most of the alluvial fan surfaces that are displaced by the Independence fault are now isolated and are well above the active channels (equal to or greater than 10 meters).

The age of these alluvial fans near the mountain front is critical with respect to documenting Holocene activity along the Independence fault zone. The age of alluvial fan surfaces along Independence Creek has been estimated by Gillespie (1982), based on relative dating techniques such as boulder weathering and soil profile development. The alluvial fan at Independence Creek, which is incised similar to other alluvial fans to the south along the mountain front, is probably mid-Wisconsin in age (30 - 40 ka) (Gillespie, 1982). Lubetkin (1980) reported that the isolated alluvial fan of Lone Pine Creek, located between Lone Pine and the Alabama Hills, was deposited during the Tioga stage (probably less than 21,000 years ago). According to Lubetkin, the larger alluvial fans west of the Alabama Hills are older than the abandoned fan at Lone Pine Creek, based on relative weathering data and geomorphic evidence. Thus, the incised alluvial fan surfaces in the FER study area are probably no younger than early Tioga (_20 ka).

At George Creek the Independence fault offsets a terrace that is probably late Tioga outwash (about 13,000 to 15,000 yrs old) (locality 18, Figure 3b). This age estimate is based on the position of the deposit in relation to the modern drainage channel and the older alluvial fan surfaces above the deposit and the lack of weathering of granitic boulders. The comparison of the constructional surfaces of this deposit with deposits of mid-Wisconsin age in the North Fork of Oak Creek mapped by Gillespie (1982) is consistent with a younger, late Tioga age for the faulted deposit in George Creek.

Lineaments North of Alabama Hills

A broad zone of discontinuous tonal lineaments is located just north of the Alabama Hills and west of Highway 395 (Figure 3b). This northwest-trending zone is delineated by a very broad, poorly defined trough and associated tonal lineaments (ground water barriers) in latest Pleistocene to Holocene alluvium. Well-defined fault-related geomorphic features generally were not observed within this broad zone, except for short, rounded, moderately defined east-facing scarps (localities 24 and 25, Figure 3b). Lineaments mapped by Slemmons and students (1970) generally were not verified along this northwest-trending zone (Figures 2b and 3b).

SEISMICITY

Seismicity in the western Owens Valley study area is depicted in Figure 4. A and B quality epicenter locations by California Institute of Technology (1985) and University of Nevada, Reno (1985) are for the period 1932 to 1985.

Seismicity in the study area is relatively quiescent (Figure 4). A few scattered epicenters may be associated with the Independence fault zone south of Independence Creek, but distinctive patterns of seismicity that can be directly related to specific fault traces are not present (Figure 4).

CONCLUSIONS

Independence Fault Zone

The Independence fault zone is a major range front fault that forms part of the Sierra Nevada fault zone. The Independence fault zone, which is characterized by Basin and Range normal faulting, has approximately 1800 meters of down-to-the-east vertical displacement (Gillespie, 1982). Gillespie reported that the Independence fault zone has an average late Quaternary slip-rate of about 0.35 mm/yr.

Gillespie reported that recent activity of the Independence fault zone is variable along the trend of the fault. This conclusion is consistent with the geomorphic expression of the fault, based on air photo interpretation and field observations by this writer. The Independence fault zone is locally moderately well to well-defined and has geomorphic evidence of latest Pleistocene to Holocene displacement, particularly in the southern part of the study area. However, adjacent areas often are poorly defined and/or lack evidence of Holocene offset.

The Independence fault zone is moderately well-defined in the southern part of the study area (including the Lone Pine, Mt. Langley, Manzanar, and Mt. Williamson 7.5-minute quadrangles) and is delineated by geomorphic evidence indicating latest Pleistocene to Holocene normal displacement (e.g. localities 8, 9, 11 to 23, Figures 3a and 3b). Fault scarp profiles in alluvial fans and terraces of late Tahoe (30 - 40 ka) to late Tioga age (13 -15 ka) further support probable Holocene activity along the Independence fault zone (e.g. localities 12, 13, 17, and 21, Figures 3a and 3b).

Traces of the Independence fault zone mapped by Slemmons and students (1970) mostly were not verified by this writer (Figures 2a-2c, 3a-3b). Significantly, the principal active traces of the Independence fault zone mapped by Moore (1963), Gillespie (1982), and this writer sometimes were not mapped by Slemmons and students or were mislocated (Figures 2a-2c, 3a-3b).

Traces of the Independence fault zone mapped by Moore (1963 and 1981) and Gillespie (1982) were locally verified by this writer, based on air photo interpretation and limited field observations (Figure 2c). However, available air photo coverage was not complete and some areas west of the Independence fault zone in the Kearsarge Peak and Aberdeen quadrangles are incompletely evaluated (Figure 2b). The fault mapped by Gillespie in Independence Creek that offsets a late Tioga outwash terrace is well-defined and was verified by this writer, based on field observations (Figure 2c). A rock avalanche deposit of probable Holocene age is offset along this branch of the Independence fault just north of Grays Meadow (Gillespie, 1982) (locality 3, Figure 2c). Gillespie reported that this strand is delineated by an approximately 2 meter-high scarp in Holocene landslide [rock avalanche] deposits (Gillespie, 1982, p. 483).

The Independence fault zone north of the Independence Creek area is moderately to poorly defined and does not offset latest Pleistocene to Holocene deposits, except where Gillespie reported probable Holocene displacement south of Sawmill Creek and at Shingle Mill Bench (localities 9 and 10, Figure 2c). The Independence fault zone mapped by Gillespie just south of Sawmill Creek is delineated by a short, moderately defined east-facing scarp in late Pleistocene alluvium that was partly verified by this writer, although differences in locations exist (locality 9, Figure 2c). The Shingle Mill Bench area is not covered by air photos, is mostly inaccessible, and therefore was not evaluated.

Lineaments North of Alabama Hills

A very broad, poorly defined trough with associated tonal lineaments is located north of the Alabama Hills and west of Highway 395 (Figures 2b and 3b). This northwest-trending zone mapped by Slemmons and students (1970) is up to 2 km wide. This northwest-trending zone forms a prominent, though diffuse, groundwater barrier in latest Pleistocene to Holocene alluvium. However, geomorphic features are not well-defined in detail and it is very difficult to recommend specific traces for zoning.

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1985).

Independence Fault Zone

Zone for Special Studies well-defined traces of the Independence fault zone mapped by Moore (1963, 1981), Gillespie (1982), and Bryant (this report) as depicted in Figures 2b-2c and 3a-3b (highlighted in yellow). Principal references cited should be Moore (1963, 1981), Gillespie (1982), and Bryant (this report).

Do not zone traces of the Independence fault zone in the northern Kearsarge Peak and Aberdeen 7.5-minute quadrangles at this time. There was insufficient aerial photographic coverage available for adequate evaluation of these strands of the Independence fault zone.

Lineaments North of Alabama Hills

Do not zone the northwest-trending lineaments north of the Alabama Hills and west of Highway 395. Specific, well-defined faults were not observed.

Reviewed, recommendations approved. Earl W. Hart 3/15/89

William A. Bryant

William A. Bryant
Associate Geologist
R.G. # 3717
March 1, 1989

REFERENCES

Bryant, William A., 1988, Owens Valley fault zone, western Inyo County, California: Division of Mines and Geology, unpublished Fault Evaluation Report FER-192, 23 p.

California Institute of Technology, 1985, Magnetic tape catalog, southern California earthquakes for the period 1932 to 1985: Seismological Laboratory, California Institute of Technology (unpublished).

Gillespie, A.R., 1982, Quaternary glaciation and tectonism in the southeastern Sierra Nevada, Inyo County, California: California Institute of Technology, unpublished Ph. D. thesis, 695 p., map scale 1:62,500.

Hanks, T.C., and Wallace, R.E., 1986, Morphologic analysis of the Lake Lahontan shoreline and beach front fault scarps, Pershing County, Nevada: Bulletin of the Seismological Society of America, v. 75, p. 835-846.

Hart, E.W., 1985, Fault-rupture hazard zones in California: California Department of Conservation Division of Mines and Geology Special Publication 42, 24p.

Knopf, A., 1918, A geologic reconnaissance of the Inyo Range and the eastern slope of the Sierra Nevada, California: U.S. Geological Survey Professional Paper 110, map scale 1:125,000.

Lubetkin, L.K.C., 1980, Late Quaternary activity along the Lone Pine fault, Owens Valley fault zone, California: Stanford University, California, unpublished M.S. thesis, 85 p.

Matthews, R.A., and Burnett, J.L., 1965, Fresno Sheet: California Division of Mines and Geology Geologic Map of California, scale 1:250,000.

Mayer, L., 1982, Constraints on morphologic-age estimation of Quaternary fault scarps based on statistical analyses of scarps in the Basin and Range province, Arizona and northeastern Sonora, Mexico: Geological Society of America Abstracts with Programs, Cordilleran Section, v. 14, no. 4, p. 213.

Moore, J.G., 1963, Geology of the Mt. Pinchot Quadrangle, southern Sierra Nevada, California: U.S. Geological Bulletin 1130, 152 p., map scale 1:62,500.

Moore, J.G., 1981, Geologic map of the Mount Whitney Quadrangle, Inyo and Tulare Counties, California: U.S. Geological Survey Geologic Quadrangle Map GQ-1545, scale 1:62,500.

Savage, J.C., Church, J.P., and Prescott, W.H., 1975, Geodetic measurement of deformation in Owens Valley, California: Bulletin of the Seismological Society of America, v. 65, p. 865-874.

Slemmons, D.B., and students, 1970, Unpublished maps of Independence, Lone Pine, and Mt. Pinchot quadrangles, Inyo County, California, showing recently active faults (based on photo geologic interpretation and limited field checking): University of Nevada, Reno, scale 1:62,500.

University of Nevada, Reno, 1968, Aerial photographs OV - 9 - 11-82 to 87, black and white, vertical (low sun angle), scale 1:12,000.

University of Nevada, Reno, 1985, Magnetic tape catalog, earthquakes for the period January 1975 to July 1985: Seismological Laboratory, University of Nevada, Reno (unpublished).

U.S. Bureau of Land Management, 1977, Aerial photographs CA01-77 1-32-1 to 3, 33-1 to 8, 34-1 to 10, 35-1 to 15; 2-37- 1 to 15; 6-38-1 to 15, 39-1 to 12, 40-1 to 5; 7-36-1 to 13, vertical, color, approximate scale 1:24,000.

U.S. Geological Survey, 1955, Aerial photographs GS-VJZ, 3-39 to 41, 85 to 91; 6-73 to 78, vertical, black and white, approximate scale 1:54,000.

Wallace, R.E., 1977, Profiles and ages of young fault scarps, north-central Nevada: Geological Society of America Bulletin, v. 88, no. 9, p. 1267-1281.

Wallace, R.E., 1978, Geometry and rates of change of fault-generated range fronts, north-central Nevada: Journal of Research of the U.S. Geological Survey, v. 6, no. 5, p. 637-650.

Photo 1 (to FER-203). The eastern front of the Sierra Nevada near Manzanar; view west. The Independence fault zone, located near the base of the range front, is delineated by scarps in late Pleistocene alluvium (arrows), faceted spurs, and "wine-glass" shaped drainage channels. Whitney Portal Road is indicated by the open arrow.

Photo 2 (to FER-203). View west of the scarp (arrows) in Independence Creek (locality 8, Figure 2c). This branch of the Independence fault zone vertically offsets a late Tioga outwash terrace 1.4 meters (Gillespie, 1982).